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Primary Teachers' Mathematics Beliefs, Teaching Practices and Curriculum Reform Experiences ®

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One hundred and twenty seven experienced classroom teachers in 21 South Australian primary schools were surveyed in Term 4, 2005 in relation to their beliefs about mathematics, beliefs about mathematics teaching and learning, pedagogical practices and curriculum reform experiences. All teachers had experienced a number of curriculum reforms in mathematics during their teaching career, with the most recent reform involving a constructivist approach to the teaching and learning of mathematics which was introduced in 2001. They had also been encouraged to use Information and Communication Technologies in their mathematics classrooms. Teachers' espoused beliefs about mathematics were unrelated to their beliefs about mathematics teaching and learning. Furthermore, teachers differed in their beliefs, with those with stronger beliefs making greater use of some constructivist teaching practices in their classrooms. Teachers experiencing a high number of reforms reported utilising computers and the internet more often in mathematics lessons and sought constructive information about student mathematics learning more frequently. While reasons why some teachers are more likely to take up reform initiatives than others who resist reforms remains a fruitful area for future research, resilient teachers who update their practices after repeated exposure to reform initiatives over time should also be investigated further.

Teachers' personal beliefs and theories about mathematics and the teaching and learning of mathematics are widely considered to play a central role in their teaching practices (Ball, 1996; Handal & Herrington, 2003; Kagan, 1992; Pajares, 1992) and implementation of curriculum reform (Handal & Herrington, 2003). However, the exact nature of the relationship between teachers' beliefs and their instructional behaviours is unclear (Buzeika, 1996) and has received scant attention from researchers (Pajares, 1992). At the classroom level teacher beliefs can facilitate or inhibit curriculum reform (Burkhardt, Fraser & Ridgway, 1990; Koehler & Grouws, 1992; Sosniak, Ethington & Varelas, 1991) as their beliefs are robust (Pajares, 1992), resistant to change (Block & Hazelip, 1995; Kagan, 1992), serve as filters for new knowledge (Nespor, 1987; Pajares, 1992) and act as barriers to changes in teaching practices (Fullan & Stiegelbaure, 1991). While some teachers either fail to take up reforms or actively resist innovations (Fullan, 1993), many others make surface changes to their teaching by adopting some of the more easily assimilated practices into their pedagogical repertoire, such as the use of manipulatives in mathematics in the primary grades (Windschilt, 2002). Hargreaves (1994) has described these superficial changes as "safe simulations" which enable teachers to embrace new innovations without disrupting the cultural norms of the classroom and more significantly without altering their fundamental beliefs. This is particularly evident in constructivist reforms where Windschilt (2002) asserts some teachers place an inordinate faith in students' ability to structure their own learning and where student activity is equated with learning (Prawat, 1992).

Numerous mathematics curriculum reforms have been attempted in many countries over the several decades but each reform has been largely unsuccessful, leading Handal and Herrington (2003, p.63) to comment that mathematics is *the subject with the highest number of fleeting innovation attempts*. The poor history of reform in mathematics has been attributed to a lack of congruence between the intent of the curriculum innovations and teachers' pedagogical knowledge, beliefs and practises (Cuban, 1993). Mismatches between the official curriculum prescribed by policy makers and the actual mathematics curriculum taught by teachers in classrooms have been demonstrated through case studies in several countries (Anderson & Piazza, 1996; Brew, Rowley & Leder, 1996; Buzeika, 1996; Desforges & Cockburn, 1998; Konting, 1998; Moreira & Noss, 1995; Sowell & Zambo, 1997; Wilson, 1990). Most reforms in mathematics have been introduced by education authorities through a top-down approach (Kyeleve & Williams, 1996; Moon, 1986) which ignores teachers' beliefs and pedagogical practices and the changes which would be necessary for them to be able to embrace the innovation (Norton, McRobbie & Cooper, 2002; Perry, Howard & Tracey, 1999). Furthermore, despite multiple reform efforts, observations of classroom pedagogical practices reveal that teachers still continue to teach mathematics as they have in the past (Sparks & Hirsh, 2006; Stigler & Hiebert, 1999). The perpetuation of traditional methods of teaching mathematics in many countries was borne out in the recent videotape study of eighth grade classrooms in Australia, the Czech Republic, Hong Kong, Japan, the Netherlands, Switzerland, and the United States conducted as part of the Third International Mathematics and Science Study (TIMSS). The predominance of traditional approaches in TIMSS was evident even in the classrooms of teachers who claimed that they used reform methods (Hiebert, Gallimore, Garnier, Bogard Givvin, Hollingsworth, Jacobs, Chui, Wearne, Smith, Kersting, Manaster, Tseng, Etterbeek, Manaster, Gonzales & Stigler, 2003). In all countries 90 percent of lessons observed made use of a textbook or worksheet of some kind, some whole-class and individual work was evident and teachers talked more than students, at a ratio of at least 8:1 words, respectively.

Teachers are central to reform in mathematics education (Battista, 1994) particularly at the primary level where all teachers are required to teach mathematics. However, Battista (1994) has asserted that most teachers are ill-prepared for the task as they have not acquired a deep understanding of mathematics (Gregg, 1995) as they are themselves products of the traditional mathematics-as-computation view of teaching in which mathematics was regarded as sets of transmitted facts and procedures. Teachers' lack of advanced conceptual knowledge in mathematics has proved to be problematic for professional developers in several studies (Akers, Berle-Carman, Douglas, Economopoulos & Nemirousky, 1997; Barrett, Jones, Mooney, Thornton, Cady, Guinee & Olson, 2002; Cohen, 1990; Olson & Barrett, 2004; Simon, Tzur, Heintz, Smith & Kinzel, 1999). However, teacher Professional Development (PD) must focus not only on subject matter knowledge (Loucks-Horsley, Love, Stiles, Mundry & Hewson, 2003) but also pedagogical content knowledge (Schulman, 1987). Within Australia the focus on pedagogical practices in mathematics in teacher PD has been considered crucial while in the United States of America PD has focussed predominantly on teachers' mathematical knowledge (White, Mitchelmore, Branca & Maxon, 2004).

For curriculum reform initiatives to be successful teachers must not only broaden their mathematical knowledge and competencies (Battista, 1994) but also challenge their prevailing attitudes and beliefs about the nature of mathematics (Sirotnik, 1999; Soder, 1999). This is particularly necessary for the incorporation of Information and Communication Technologies (ICT) into the teaching and learning of mathematics, as use of ICT requires teachers to shift from traditional transmission views of mathematics pedagogy (National Research Council, 1989; Perry, Howard & Conroy, 1996) to more child-centred constructivist views (Perry *et al.,* 1999). For reforms to be implemented effectively, teachers must be given opportunities to engage in substantive professional learning (PL) over extended periods of time (Darling-Hammond, 1996). The need for PL to occur over long time periods is stressed in the *Professional Development Analysis* (Snow-Renner & Lauer, 2005) which cites case studies from the United States of America indicating that teachers experiencing 80 hours (Corcoran, McVay & Riordan, 2003; Sopovitz & Turner, 2000) and 160 hours (Sopovitz & Turner, 2000) of PD respectively were more likely to use reform based instruction in Science than teachers who receive fewer hours. While actual time allocations for PL in mathematics are rarely cited, it is generally agreed that time is a critical ingredient in the effective implement of reform (Boyd, Banilower, Pasley & Weiss, 2003; Wilson & Berne, 1999), as changes in teacher instruction take place slowly (Snow-Renner & Lauer, 2005) with some teachers continuing to struggle with aspects of reform initiatives several years after their introduction (Pasley, 2002). In the recent Programme for International Student Assessment (PISA) studies, Australian teacher were ranked as third in the world alongside the United Kingdom, Sweden & United States of America in terms of their rates of participation in PL (McKenzie & Santiago, 2004), based on evidence from school principals that 64% of teachers had participated in some form of PD of at least one day's duration over three months. While other studies confirm the overwhelming majority of teachers do participate in some PL activities in any one year (Skilbeck & Connell, 2003), an Australian survey found teacher participation to be very uneven with several gaps or discontinuities evident (McRae, Ainsworth, Groves, Rowland & Zbar, 2001). Overall, teacher PL is considered to be fragmented and piecemeal (Wilson & Berne, 1999), with great variations existing between schools and even between teachers within the same school (McRae *et al.,* 2001). In Australia, teacher PL continues to be very largely a matter of school and/or individual teacher choice (Skilbeck & Connell, 2003), with the success of the PL activities depending very much on teacher motivation, enthusiasm and commitment (White *et al.,* 2004). Furthermore, time allocations and attendance at PL activities do not of themselves guarantee changes in teachers' learning and practices (Wilson & Berne, 1999) as many teachers often seek new tools, techniques and "tricks of the trade" with which to reinvigorate their teaching rather than the acquisition of professional knowledge per se (Wilson & Berne, 1999).

THE PRESENT STUDY

The present study was designed to investigate relationships between teachers' beliefs about mathematics and the teaching and learning of mathematics, their pedagogical practices in mathematics and their experiences of curriculum reforms in mathematics. The study took place in South Australian Department of Education and Children's Services (DECS) primary schools and involved teachers with 10 or more years of teaching mathematics. DECS schools were chosen for the study as a *South Australian Curriculum Standards and Accountability Framework* (SACSA) had been introduced across all curriculum areas in 2001 and the use of ICT nominated as a strategic direction for mathematics education. SACSA is based on constructivism which *views learning as an active process in which learners construct new ideas or concepts based on their current and past understandings* (DECS, 2001). Thus all teachers who participated in the study had taught mathematics prior to and after the introduction of the SACSA framework.

Aims of the study

The study had four aims:

1 To investigate teachers' espoused beliefs about mathematics and the teaching and learning of mathematics;

2 To examine teachers' pedagogical practices in mathematics;

3 To appraise teachers' experiences of curriculum reforms in mathematics; and

4 To explore relationships between teachers' espoused beliefs about mathematics and the teaching and learning of mathematics, their pedagogical practices and reform experiences.

METHOD

Participants

One hundred and twenty-seven experienced primary teachers in 21 DECS schools participated in the study. The 29 male and 98 female teachers ranged in age from 30 to 62 years with a median age of 51 years. Sixty-four of the teachers had a basic teaching qualification, 45 held a Bachelor degree and 18 had postgraduate qualifications. None of the teachers had formal qualifications in mathematics education.

The Survey

The four page survey consisted of items measuring teachers' age, gender, qualifications, years of teaching mathematics, beliefs and practices in mathematics and experiences of curriculum reforms. Teachers identified their qualifications and length of time teaching mathematics from tables provided in the survey. Their beliefs about mathematics and the teaching and learning of mathematics were measured on 20 items developed by Perry *et al.,* (1996) from various mathematics education reform statements (Australian Education Council, 1991; Mumme & Weissglass, 1991; Wood, Cobb & Yackel, 1992). However, the response format was amended from the three point rating scale used by Perry *et al.* (1996) to a four point scale ranging from 1 (*strongly disagree*), 2 *(disagree)*, 3 *(agree)* to 4 (*strongly agree*). Teachers indicated how much time they thought should *ideally* be allocated to mathematics lessons per week, how much time they *allocated* to mathematics on their weekly timetables and how much time they *actually* spent on mathematics lessons each week and rated 10 statements about their current use of mathematics classroom pedagogy in relation to assessment, use of manipulatives, worksheets, textbooks and ICT (calculators, computers and the internet) on a four point scale from 1 (*never used*), 2 (*occasionally used*), 3 (*used once or twice a week*) to 4 (*daily use*). Teachers identified curriculum reforms in mathematics they had experienced from a list of 15 reforms introduced since the 1960s. These reforms included mathematics education innovations such as Cuisenaire and New Maths that had been enacted in many countries, reforms that had been initiated across all curriculum areas in Australia such as the national Statements and Profiles (Watt, 2004) and specific DECS reforms including the SACSA framework.

Procedure

Introductory letters were sent to 21 primary school Principals in South Australia inviting teachers within their school with 10 or more years of experience of teaching mathematics to participate in the study. These letters were then followed up by a telephone call to each Principal to identify eligible teachers to whom a letter of introduction, information sheet about the study and consent form were sent in a sealed envelope. Surveys were distributed in Term 4, 2005 to the selected teachers in each school who had returned a consent form and their completed surveys were returned by reply-paid post between October and December, 2005.

RESULTS

All survey data for the 127 teachers were entered into an SPSS programme and measures of central tendency, correlational and factor analyses conducted. Years of teaching mathematics were categorised in five yearly increments, with the final increment measuring 31 or more years of teaching. Teachers who participated in the study had been teaching mathematics from 10 to 31+ years with a median range of 26 to 30 years and had experienced between 2 to 15 curriculum reforms, with a median of 9 reforms. Teachers reported time allocations for *ideal, allocated* and *actual* time for mathematics lessons per week were converted to minutes and categorised on a 7 point scale, with 1 = 180 -210 minutes, 2 = 220 – 240 minutes, 3 = 250 – 270 minutes, 4 = 280 – 300 minutes, 5 = 310 – 330 minutes, 6 = 340 – 360 minutes and 7 = 370 – 450 minutes. Repeated measures ANOVA indicated an overall statistically significant effect for time measures F (1, 107) = 19.9, p< 0.001). Follow up analyses revealed statistically significant differences between *ideal* and *actual* time allocations for mathematic lessons F (1, 107) = 19.9, *allocated* and *actual* time F (1, 107) = 8.4 and *ideal* and *allocated* time F (1, 107) = 10.9.

The 20 items measuring teachers' beliefs about mathematics and about the teaching and learning of mathematics (Perry *et al.*, 1996) were analysed with Principal Components Analysis, with the factor loadings shown in Table 1 based on an Oblimin two factor resolution. Mean scores in Table 1 are expressed on a 4 point scale from 1 (*strongly disagree*) to 4 (*strongly agree*). Factor 1 is composed of eight items reflecting teachers' constructivist beliefs about the teaching and learning of mathematics and Factor 2 four items reflecting teachers' beliefs about the beauty and meaningfulness of mathematics. The factor scores correlation of 0.11 is not statistically significant.

Table 1: Factor analysis of teachers' espoused beliefs

Factor 1: Teachers' constructivist beliefs about mathematics teaching and learning			
No.	Item	Loading	Mean
14	Mathematics learning is enhanced by challenge within a supportive environment	0.60	3.64
13	Mathematics learning is enhanced by activities which build upon and respect students' experiences	0.60	3.46
17	The role of the mathematics teacher is to transmit mathematical knowledge and to verify that learners have received this knowledge (R)	-0.57	2.33
2	Mathematics problems given to students should be solvable quickly in a few steps (R)	-0.56	2.15
19	Teachers should negotiate social norms with the students in order to develop a cooperative learning environment in which students can construct their knowledge	0.53	3.23
10	Periods of uncertainty, conflict, confusion and surprise are a significant part of the mathematics learning process	0.53	3.18
1	Mathematics is computation (R)	-0.53	2.49
18	Teachers should recognise that what seem like errors and confusions from an adult point of view are students' expressions of their current understanding	0.51	3.20
Factor 2 Teachers' beliefs about the beauty and meaningfulness of mathematics			
7	Mathematics knowledge is the result of the learner interpreting and organising the information gained from experiences	0.65	3.24
3	Mathematics is the dynamic searching for order and pattern in the learner's environment	0.58	3.29
5	Mathematics is a beautiful, creative and useful human endeavour that is both a way of knowing and a way of thinking	0.55	3.09
8	Students are rational decision makers capable of determining for	0.51	2.49

	themselves what is right and wrong		

Note. (R) = reversed item

The distribution of Factor 1 teachers' constructivist beliefs about mathematics teaching and learning is presented in Figure 1 and the distribution of Factor 2 teachers' beliefs about the beauty and meaningfulness of mathematics in Figure 2.

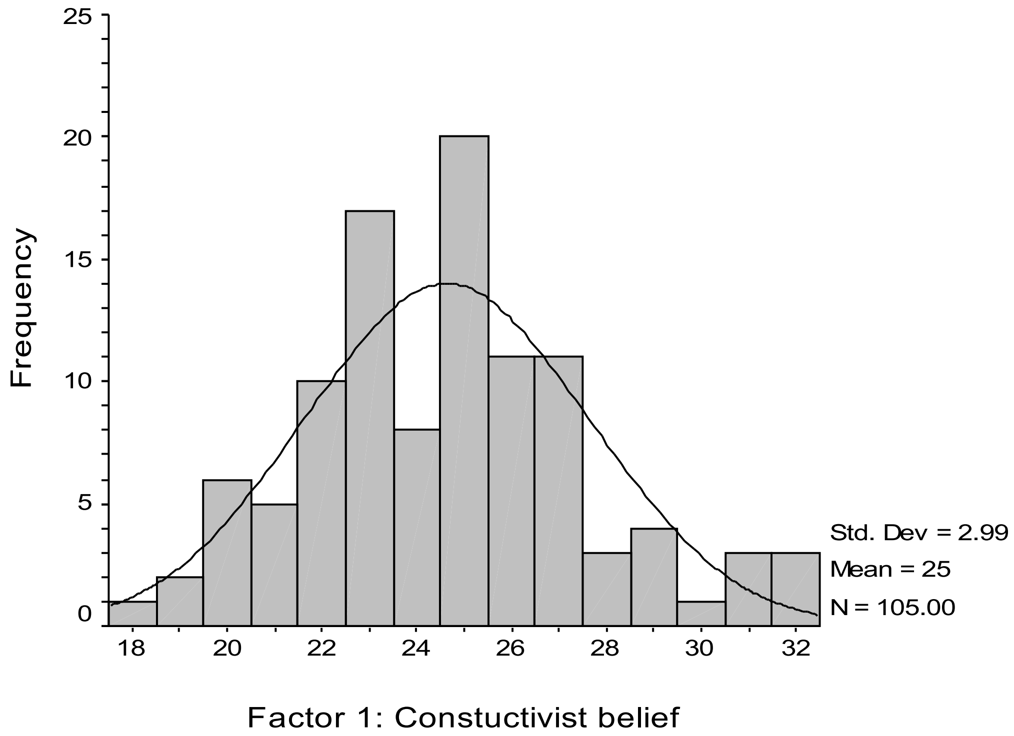

Figure 1 Teachers' constructivist beliefs about mathematics

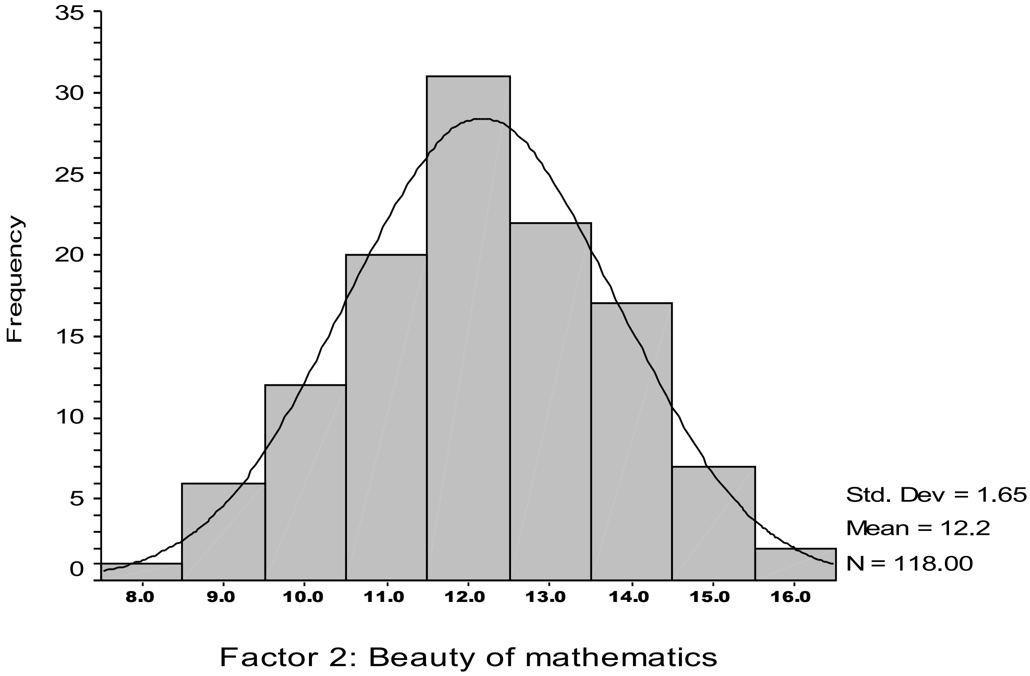

Figure 2 Teachers' beliefs about the beauty and meaningfulness of mathematics

Factor 1 and Factor 2 were then used to explore relationships between teachers' espoused beliefs about mathematics and mathematics teaching and learning, ideal, timetabled and actual time allocations for mathematics lessons, reported use of some pedagogical practices, and curriculum reform experiences.

No statistically significant relationships were found between teachers' constructivist beliefs about mathematics and any of the time allocations for mathematics lessons. Similarly, no statistically significant correlations were found between their beliefs in the beauty and meaningfulness of mathematics and any of the three measures of time allocation for mathematics lessons.

Relationships between teachers' constructivist beliefs about the teaching and learning of mathematics and their reported practices were investigated with analysis of variance (ANOVA), with the results presented in Table 2. Teachers were grouped in relation to Factor 1 by means of a quartile split, with 26 teachers scoring in the upper quartile (Mean = 28.6 out of a possible 32) and 29 teachers scoring in the lower quartile (Mean = 20.9). The ANOVA revealed statistically significant differences between these two groups of teachers in three of the 10 teaching practices measured by the survey (see Table 2).

Table 2: ANOVA of teacher constructivist beliefs and teaching practices

Reported teaching practices	High v's low constructivist teacher means
Students in my class use manipulatives during maths lessons	3.24 versus 2.69 $F(1, 53) = 7.1$, $p = 0.01$
I give students worksheets in maths lessons	2.24 versus 2.58 $F(1, 53) = 4.6$, $p = 0.04$
I use tests to assess student knowledge and understanding of maths	2.00 versus 2.23 $F(1, 53) = 3.01$, $p = 0.08$

Statistically significant correlations between teachers' beliefs in the beauty and meaningfulness of mathematics were found for two teaching practices as shown in Table 3. The positive correlation between Factor 2 and use of manipulatives indicates that teachers with stronger beliefs in the beauty and meaningfulness of mathematics used manipulatives more frequently with students, while the negative correlation indicates less frequent use of worksheets in their classrooms.

Table 3: Correlations between teacher beliefs about the beauty and meaningfulness of mathematics and teaching practices.

Relationships between teachers' beliefs about mathematics and practices	*r*
Students in my class use manipulatives during maths lessons	0.22*
I give students worksheets in maths lessons	- 0.22*

*$p = 0.05$ (2-tailed)

The number of curriculum reforms teachers reported having experienced was not statistically significantly related to either their Factor 1 constructivist teaching beliefs or Factor 2 beliefs about the beauty of mathematics. Moreover, teacher age, qualifications and length of mathematics teaching experience were not statistically significantly related to Factor 1, Factor 2 or any of the 10 teaching practices measured in the survey. However, the number of reforms experienced was statistically significantly related to four teaching practices as shown in Table 4. Teachers who scored highly on the number of reforms encountered needed to know what students understood in mathematics more often. They also reported using tests, computers, and the internet more frequently with students.

Table 4: Correlations between reforms experienced by teachers and their practices.

Relationship between number of curriculum reforms and teaching practices	*r*
I use tests to assess student knowledge and understanding of maths	0.18*
Students in my class use a computer during maths lessons	0.20*
I need to know what student have understood in maths	0.18*
Students in my class use the internet during maths lessons	0.18*

*$p = 0.05$ (2-tailed)

DISCUSSION

Battista (1994, p. 468) paints a somewhat dismal picture of experienced primary school teachers caught in a *pernicious cycle of mathematical mislearning*, whereby their traditional beliefs serve to block their enactment of curriculum innovations. When presented with reform initiatives some teachers resist changing their practices while other more resilient teachers make superficial, cosmetic changes to their teaching practices in the classroom without really fully understanding the underlying principles and rationale for the reform changes (Fullan & Stiegelbaure, 1991). Teachers' beliefs about the nature of mathematics measured in the survey were not statistically significantly related to their beliefs about the teaching and learning of mathematics. Furthermore, Figures 1 and 2 show that the experienced teachers who participated in this study differed in their beliefs about mathematics and the teaching and learning of mathematics. However, for the majority of teachers there was no statistically significant relationship between their beliefs about the nature of mathematics or the teaching and learning of the subject matter and their reported pedagogical practices. It was only those with strong views about the beauty of mathematics and those scoring highly on constructivism who reported statistically significantly more frequent use of the more easily assimilated (Windschilt, 2002), safely simulated (Hargreaves, 1994) child-centred practices in their classrooms. Furthermore, teachers' beliefs were not related to their age, qualifications or length of mathematics teaching experience, suggesting that their beliefs had probably been formed through an *apprenticeship of observation* (Lortie, 1975) from their own experiences as students in mathematics classrooms (Bullough, 1997; Ethell, 1997; Fang, 1996; Pajares, 1992; Richardson, 1996) and had remained largely unchanged over time (Block & Hazelip, 1995; Kagan, 1992). Further evidence of the robustness and immutability of teacher beliefs is discernible in the lack of statistically significant relationships between their beliefs as measured in Factor 1 and 2 and the ideal, timetabled or actual time allocations that they assigned to mathematics lessons.

However, teacher beliefs tell only half the story (Kane, Sandretto & Heath, 2002) as reform initiatives also depend on teacher knowledge of the curriculum subject matter. The average age of the primary teachers who participated in this study indicate clearly that they would have received their own mathematics education during the rule-based transmission view of mathematics-as-procedures era (Battista, 1994). Thus the question of whether they have a sufficiently deep level of knowledge of mathematics to enact most reforms in mathematics and the recent DECS constructivist curriculum reform in particular needs to be investigated further. Many of the mathematics curriculum reforms that the teachers in this study had experienced were introduced during the earlier phases of PD in Australia (McRae *et al.,* 2001) which were characterised by a didactic style of delivery and highly centralised control of the Training and Development agenda. More recent professional learning activities across Australia utilise a range of delivery modes (Ingvarson, Meiers, & Beavis, 2005) but have tended to focus on pedagogy and curriculum rather than teacher subject knowledge (Skilbeck & Connell, 2003), particularly in mathematics (White *et al.,* 2004). Furthermore, clear cut patterns of PL activity in Australia are difficult to discern overall, with most teachers engaging in what has been variously described as an episodic, kaleidoscopic (Skilbeck & Connell, 2003), patchwork quilt of topics (McCrae *et al*., 2001).

While the finding that teacher age, qualifications and length of mathematics teaching experience were not statistically significantly related to their teaching practices is somewhat unexpected, the statistically significant relationship between the sheer number of reforms experienced by teachers and their use of ICT and some assessment practices is of particular interest. Teachers in this study had been teaching mathematics on average from 26 to 30 years and had experienced an average of nine curriculum reforms over that time which means that on average they had experienced one reform every three years. While most were mathematics education reforms enacted in many countries, one was a national initiative across Australia and others were initiated solely by DECS. The cumulative effects of numerous reform experiences on some teaching practices would suggest a reconsideration of the general consensus that mathematics education innovations have failed overall (Battista, 1994; Handal & Herrington, 2003). Educational change takes place slowly over time (Eltis & Mowbray, 1997), with substantive changes in teacher instructional practices taking a considerable period of time to become established (Snow-Renner & Lauer, 2005). While reasons why some teachers are more likely to take up reform initiatives remains a fruitful area for future research, it appears that repeated exposure to reform initiatives over time caused some resilient teachers to change their practices at least at the superficial level. However, the finding that for most teachers these practices were not related to either their beliefs about mathematics or beliefs about the teaching and learning of mathematics would confirm Huberman's (1993; 1995) view that "bricolage" or tinkering" takes place in response to reform efforts. That is, teachers incorporate some of the new techniques, activities, materials into their practices as evidenced by their statistically significantly greater use of ICT in the classroom and more frequent need for constructive information about student mathematics learning, but do not change their fundamental beliefs about mathematics and its teaching and learning (Huberman, 1994).

Elmore and Burney (1997, p.1) consider *there is a growing consensus among educational reformers that professional development for teachers and administrators lies at the centre of all educational reform and instructional improvement.* PD has become the panacea of reform efforts, but understanding of the breadth, depth, and nature of teacher learning experiences remains limited **(Scribner, 1999).** The National Council of Teachers of Mathematics (1999) has identified the critical need for collaboration between researchers and teachers if mathematics education research is to be responsive to questions regarding pedagogy and student learning. This study identified some statistically significant relationships between teachers' experiences of curriculum reforms in mathematics and their beliefs and practices at the primary level. The survey data gathered in this study will be enriched by examining teachers' written accounts of their experiences with curriculum reforms, interviews with experienced teachers and observations of their practices in the classroom. The study will also be extended to include middle school teachers so as to encompass the teaching and learning of mathematics across the compulsory years of schooling.

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